



# **DESIGN AND EXECUTION OF PREVENTIVE MAINTENANCE PROGRAM**

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Bachelor's thesis  
April 2014  
Mechanical and Production  
Engineering  
Product Development

TAMPEREEN AMMATTIKORKEAKOULU  
Tampere University of Applied Sciences

## TIIVISTELMÄ

Tampereen ammattikorkeakoulu  
Kone- ja tuotantotekniikka  
Tuotekehitys

JUHO SELIN:

Design and execution of preventive maintenance program

Opinnäytetyö 49 sivua, joista liitteitä 0 sivua  
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Tämä opinnäytetyö käsittelee ennakkohuoltosuunnitelman laatimista Purso Oy:n konepajan laitteisiin. Työn tarkoitus oli laatia valituille laitteille ennakkohuoltosuunnitelma, joka nostaisi laitteiden luotettavuutta, elinikää ja käyttöastetta.

Opinnäytetyön ensimmäinen osa käsittelee kunnossapidon teoriaa yleisellä tasolla. Sen tavoite on antaa lukijalle lähtökohta, jonka avulla myöhemmin esiteltävää ennakkohuoltosuunnitelman toteutusprosessia ja päätöksiä on helpompi ymmärtää.

Opinnäytetyön työosuudessa määriteltiin laitteiden ennakkohuoltotarpeet sekä laadittiin asianmukaiset ennakkohuoltosuunnitelmat ja niitä tukevat dokumentit. Työosuudessa myös käydään läpi prosessin aikana ilmenneitä ongelmia ja niiden ratkaisua.

Opinnäytetyön tuloksena saatiin aikaiseksi ennakkohuolto-ohjelma Purso Oy:n kevytmetallikonepajan koneille. Lisäksi laadittiin huolto-ohjeet kriittisimmille kevytmetallikonepajan laitteille. Salassapitovelvollisuuden vuoksi tämän työn liitteet pidetään salaisina.

## **ABSTRACT**

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This Bachelor's thesis describes a preventive maintenance program project conducted for Purso Oy. The objective of this project was to create a preventive maintenance program for the chosen equipment of Purso Oy. The aim of the preventive maintenance program was to induce a high reliability production environment, to increase the useful lifecycle of the machines involved, and to increase the overall capacity utilization rate.

The first part of this thesis deals with maintenance theory in general, creating a foundation on which the practical applications of the latter part can be understood. The second part of this thesis describes how the design process for the preventive maintenance program was carried out. In the practical part of the work, preventive maintenance tasks were determined, and the preventive maintenance program was formulated. The practical part also reflects upon different issues and problems encountered during the preventive maintenance program process.

As a result of this thesis a preventive maintenance program for the light metal workshop of Purso Oy was created. Moreover, maintenance instructions were compiled for the most critical machines of the light metal workshop. The appendices of this thesis include confidential material and are therefore omitted from the public version of the thesis.

Key words: maintenance, preventive maintenance

## CONTENT

1	INTRODUCTION.....	7
2	PURSO OY .....	8
2.1	Company profile .....	8
3	MAINTENANCE.....	9
3.1	Definition of maintenance.....	9
3.2	Financial justification for maintenance.....	10
3.3	Objective of maintenance .....	12
3.4	Maintenance performance.....	14
4	TYPES OF MAINTENANCE .....	15
4.1	Maintenance classifications .....	15
4.2	Improvement maintenance.....	16
4.3	Corrective maintenance .....	17
4.4	Preventive maintenance .....	18
4.4.1	Time-driven preventive maintenance.....	20
4.4.2	Condition-driven preventive maintenance .....	22
4.4.3	Involving operators to preventive maintenance .....	23
4.4.4	Requirements of preventive maintenance .....	24
4.4.5	Advantages of preventive maintenance .....	26
4.4.6	Disadvantages of preventive maintenance .....	28
5	THEORY OF DESIGNING A MAINTENANCE PROGRAM.....	29
6	THEORY OF DESIGNING A PREVENTIVE MAINTENANCE PROGRAM .....	31
7	CREATION OF THE PREVENTIVE MAINTENANCE PLAN .....	33
7.1	Mission statement .....	33
7.2	Planning and objectives .....	34
7.3	Starting phase.....	35
7.4	Planning the preventive maintenance program.....	36
7.5	Identifying PM needs.....	37
7.5.1	Criticality analysis.....	37
7.5.2	Data collection .....	38
7.6	Resolving the maintenance intervals .....	39
7.7	Resolving the preventive maintenance tasks .....	39
7.7.1	Machine 1.....	41
7.7.2	Machine 2.....	42
7.8	Creation of the preventive maintenance program.....	43

7.9	Creation of maintenance instructions .....	44
7.10	Scheduling .....	45
7.11	Implementation .....	46
8	CONCLUSION .....	47
9	References .....	48

**ABBREVIATIONS**

CMMS	Computerized maintenance management system
MTBF	Mean time between failures
MTTF	Mean time to failure
MTTR	Mean time to repair
ODR	Operator Driven Reliability
PM	Preventive maintenance
ROI	Return on Investment
TPM	Total Productive Maintenance

## 1 INTRODUCTION

The topic of this thesis is design and implementation of preventive maintenance program to the light metal workshop of Purso Oy. The growth of workshop department has driven the need for a new preventive maintenance program in order to respond to arising maintenance issues brought about by increased production capacity demands. In this case, the production capacity demand was solved by investing into new machines.

It is of course in company's best interest to guard its investments so as to receive the best return on its investment. In order to fully utilize and maintain the value of capital invested, a preventive maintenance program is required. Hence Purso Oy ordered preventive maintenance programs for the new machines, and an overhaul of existing preventive maintenance plans.

The objective of this thesis is to describe the actions taken to design the preventive maintenance program and to reflect on different problems and issues of executing the work. A brief literature preview is included in order to explain the rationale behind the PM program decisions.

## **2 PURSO OY**

### **2.1 Company profile**

Purso Oy is a company with long history in Finland's basic industry. The company was founded in 1959 with five employees. Nowadays Purso has premises in Siuro and Ikaalinen, with a total of 230 employees. Purso Oy is part of the Purso Group. Other companies in the Purso Group are Linjapinta Oy, Fennosteel Oy, Purso-Tools Oy and Veme Oy. (Purso Oy, 2013)

The main products of Purso Oy are different aluminium profiles. In year 2012 the operating division delivered over 17 000 tons of aluminium. Purso Oy masters the extrusion process all the way from the raw material to the finished product. Purso's own aluminium foundry produces over half of used aluminium. (Purso Oy, 2013)

Purso Oy aims at comprehensive customer satisfaction. Therefore the company also offers different refining services, including surface treatments, cutting, stamping, bending, welding and drilling. These refinement procedures are performed according to the customer's needs and requirements. (Purso Oy, 2013)



### 3 MAINTENANCE

#### 3.1 Definition of maintenance

The European Union standard SFS-EN 13306 defines maintenance as “combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function.” (Finnish Standards Association, 2010).

The definition of standard SFS-EN 13306 brings forth the conclusion that maintenance is about preserving the operational condition of machines, or alternatively restoring the functionality of machines. This traditional definition provided by standard SFS-EN 13306, however, is far too narrow for modern maintenance purposes. In modern plant settings, maintenance is seen as retaining, adjusting and improving the productive capacity of production assets (Järviö & Lehtiö, 2012).

If this broadened scope of maintenance is accepted, it entails a larger set of operations, such as retaining of operational performance, safety, production quality, lifecycle management, operation conditions, modernization and fixing of weaknesses. In order to match modern requirements, maintenance can no longer only include servicing and repairing of machinery, but must also include pre-emptive operations performed to maintain the functionality of machines. Pre-emptive operations may include processes such as tracking, analysis, consultation and the like. (Järviö & Lehtiö, 2012)

### 3.2 Financial justification for maintenance

The premise that good maintenance practices are fundamental to company's production objectives is beyond question. However maintenance is often viewed as a necessary evil of production and thus its full potential is rarely realized. A 2004 survey conveyed that 70% of the respondents considered maintenance as a cost center instead of a value adding process (Salonen & Deleryd, 2011). Moreover, production improvements are often not recognized to be by dint of maintenance, but often production units get the credit for production improvements achieved by maintenance. These kind of outdated outlooks on maintenance have hitherto affected the rep the maintenance management has got in the business of manufacturing. Despite its underratedness, maintenance plays a critical role in company's ability to compete. (Pintelon;Pinjala & Vereecke, 2006) (Mobley, 2002, p. 2)

In the countries of European Union, consumption on maintenance has been estimated to be 5% of total turnover. Depending on industry, maintenance expenditures range from 5% to 14% (Willmott & McCarthy, 2001). A survey of maintenance management effectiveness concluded that 33% of all maintenance costs are wasted on unnecessary or improperly carried out maintenances (Mobley, 2002, p. 1). Moreover, maintenance spending constitutes a large part of the operating budget of companies with large investments in equipment (Salonen & Deleryd, 2011). Also, when looking at maintenance expenditure's effect on profits, it has been concluded that a reduction of 1 million in maintenance expenses contributes as much to profits as increasing sales by 3 million (Ben-Daya et. al, 2009, p. 17).

In this light it becomes clear that maintenance solutions have a tremendous impact on production capacity and profit of a company (Jabar) (Dunn S. , 1996). Moreover, maintenance management significantly affects the quality of manufactured products (figure 1) (Mobley, 2002, p. 1). Thus one can easily deduce the importance of maintenance for the company's ability to compete in the very competitive modern environment.

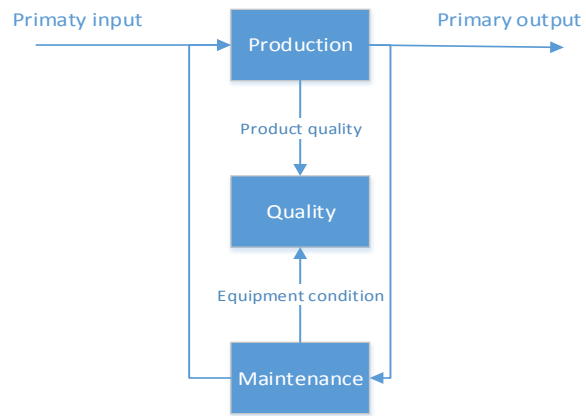


Figure 1 Effect of maintenance on the quality (Ben-Daya et. al, 2009)

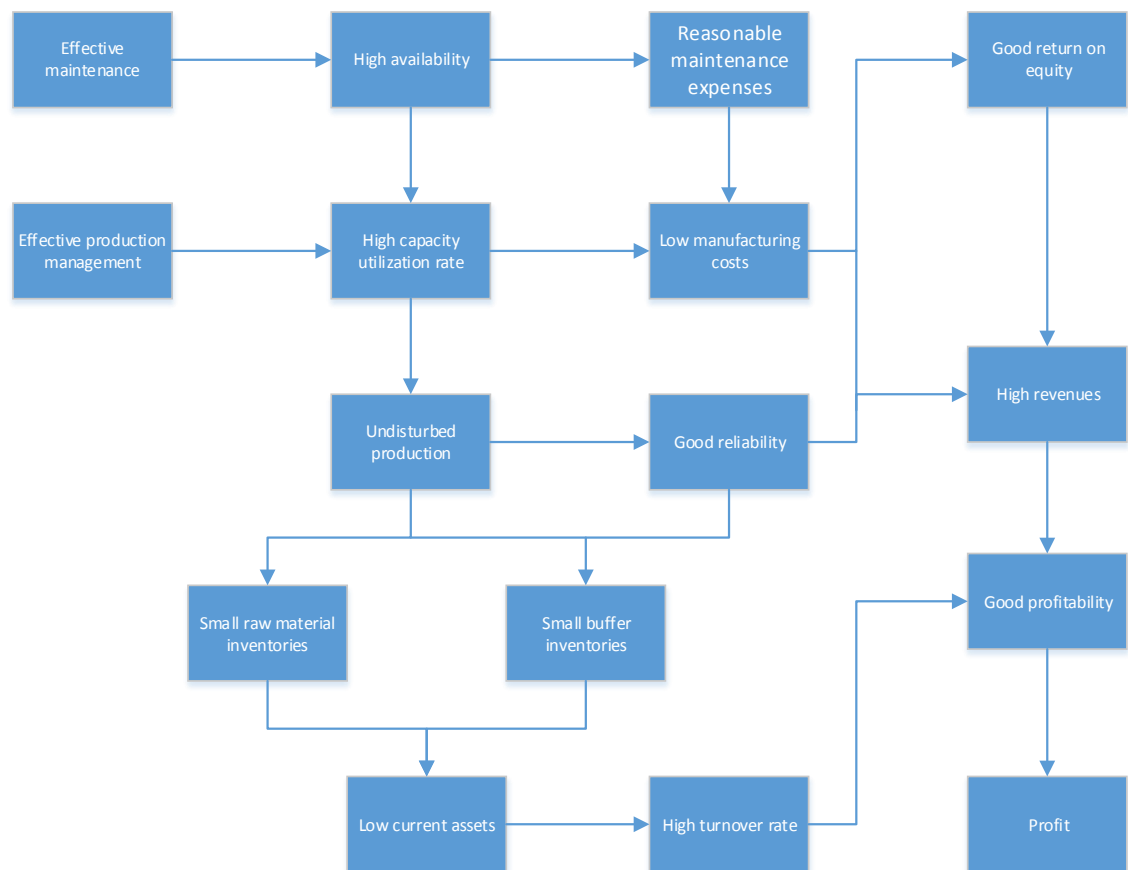


Figure 2 Effect of maintenance on profit (Järviö & Lehtiö, 2012)

### 3.3 Objective of maintenance

It is often erroneously thought that the role of maintenance department is to repair broken machinery. This is a horribly outdated point of view, but unfortunately many companies still adopt this outdated notion. The true objective of maintenance is to maintain the production machinery in a condition that enables the company to meet its production goals while minimizing maintenance expenses. This means that maintenance objective rises from the balance between maintenance resource allocation and plant outputs requirements. (Kelly, Strategic Maintenance Planning, 2006, p. 68) (Mobley, 2002, p. 43)

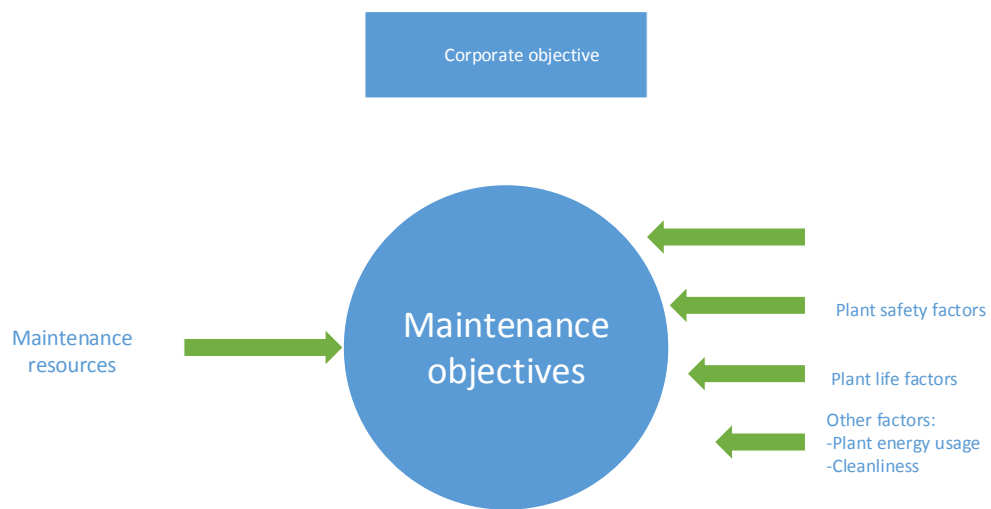


Figure 3 Maintenance objectives (Kelly, Strategic Maintenance Planning, 2006)

So maintenance objectives are always case specific and depend largely on the business objectives and given resources. However, the notion that the ultimate reason for maintenance is to maximize business profit and offer competitive advantage is well accepted and supported (Mobley, 2002, p. 43) (Cholasuke; Bhardwa & Antony, 2004). There are some general, well-established, objectives an effective maintenance organization should be able to accomplish in order to maximize its productivity and the profit of the company.

The first objective of any maintenance organization is to maintain optimum availability of equipment by avoiding breakdowns. In order to achieve optimum availability faults must occur as seldomly as possible and must be quickly addressed (Mobley, 2002, p. 44) (Järviö & Lehtiö, 2012). Maintaining optimum availability is a good starting point for a maintenance organization. However, if the aim is to develop a world-class maintenance organization, maintaining optimum availability is not nearly enough. A world-class maintenance organization aims to eliminate all equipment and system related losses while conducting its operations in the most cost-efficient way possible.

To reach world-class level maintenance must also seek to maintain plant machinery in optimum working condition. Optimum working condition enables production of quality products and minimizes production of sub-quality products. Another goal of maintenance organization is optimal use of its resources. Therefore maintenance tasks should be planned in advance and spare part inventories should always be kept to a minimum to avoid unnecessary costs (Cholasuke; Bhardwa & Antony, 2004) (Alsyouf, 2004).

Increasing the useful life of plant equipment is one way for the maintenance organization to improve the return of invested capital and that way support the business goals of the company. (Järviö & Lehtiö, 2012) (Mobley, 2002, p. 44)

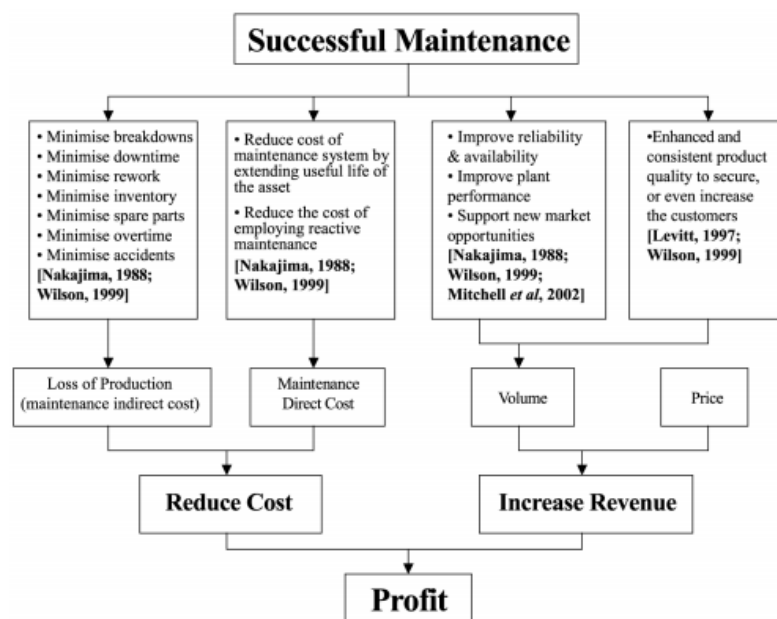


Figure 4 Effects of maintenance objectives on company's profit (Cholasuke; Bhardwa & Antony, 2004)

### 3.4 Maintenance performance

The purpose of measuring maintenance performance is to receive information for planning, controlling and forecasting. Information needs to focus on efficiency and effectiveness of the maintenance procedures. Measuring maintenance performance is important because maintenance is an important support function in business and usually one of the biggest uncontrolled costs of a company. (Parida & Kumar, 2006)

When a breakdown happens, it is usually easy to show that lack of maintenance was the reason. The opposite is true when a breakdown doesn't happen. It is generally difficult to show that maintenance prevented a breakdown. (Dunn, 1998) Therefore management usually focuses on how much maintenance costs, not on how much value maintenance added. That is why maintenance performance is generally measured. It is a tool that helps gauge the amount of value created by maintenance. (Parida & Kumar, 2006)

By measuring maintenance performance managers can determine how much value maintenance is creating, in that way managers can steer the maintenance organization to doing the right things and possible issues within the organization can be addressed (Arts; Gerald & Mann, 1998). Second reason to measure performance is justification of maintenance investments. This gives some credibility to maintenance investments as the management is able to see exactly how much is ROI. Without effective measures it's hard to justify expensive maintenance investments to the management of a company. Third reason to measure is to revise resource allocations. Based on performance measurements, managers can either change the organizational structure of maintenance or assign more resources to maintenance. (Parida & Kumar, 2006)

Rudimentary maintenance performance measures generally consist of things like availability, reliability, quality and MTBF measures (Ben-Daya et. al, 2009, s. 19). Other popular measures are total maintenance cost divided by total sales and preventive maintenance percentage divided by total maintenance percentage.

## 4 TYPES OF MAINTENANCE

### 4.1 Maintenance classifications

Standard SFS-EN 13306 separates maintenance procedures into two categories based on the type of fault detection, and this is the classification used in this thesis as well. Preventive maintenance includes all the procedures performed before the fault impedes the functioning of the machine. Corrective maintenance comprises all the procedures executed after the fault occurs. Improvement maintenance is not included in the standard (Finnish Standards Association, 2010) description of maintenance types, but is included by some authors (Mobley, 2004, p. 9). However, despite this differing viewpoint, improvement maintenance is included to the classifications. Improvement maintenance is included in the classification of maintenance because it plays an important, but often underutilized, role in maintenance management by attempting to eliminate the source cause of faults. It is classified as its own type of maintenance because it shares features of both reactive and proactive approaches.

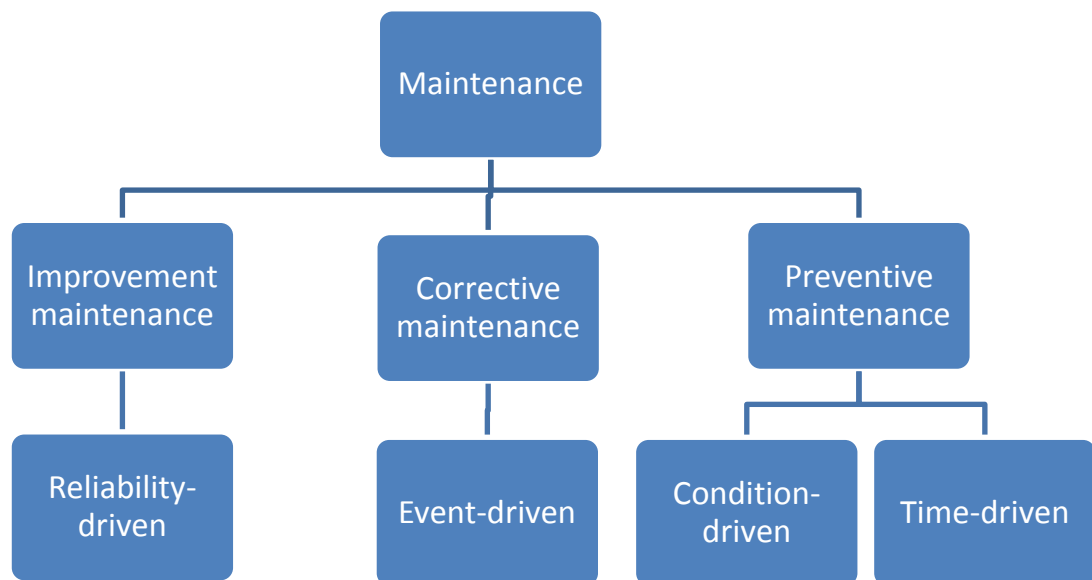


Figure 5 Maintenance classifications

## 4.2 Improvement maintenance

As stated in the Maintenance classification section, improvement maintenance shares features of both corrective and preventive maintenance. Firstly, a fault or series of faults must occur before improvement maintenance can take place. Ergo, it is event-driven and could therefore be a sub-class of corrective maintenance. However, it also attempts to prevent future events, which is a feature of preventive maintenance.

Improvement maintenance attempts to eliminate the possibility of a fault all together by identifying commonly occurring faults, and then planning and carrying out modifications and improvements to the existing machine design. By carrying out improvement maintenance the maintenance organization attempts to minimize the occurrence of critical, production halting, failures or at the very least ease the repair operations. (Mobley, 2004, p. 8) Improvement maintenance can also be utilized to improve the production efficiency of the machine. For example, old machines can be updated to increase their production capacity.

Effective use of improvement maintenance requires a history of fault occurrence. This kind of tracking is usually best achieved by employing CMMS, which tracks fault history and performed maintenance works. Often the maintenance organization is so caught up in maintaining that it's easy to overlook the need to eliminate the source causes. On the other hand, sometimes the root cause is not properly understood. This leads to correcting the symptoms instead of realizing the true cause. Improvement maintenance always aims to identify the root cause and to make the necessary improvements to the machine in order to avoid reoccurrence of the fault. (Mobley, 2004, p. 8)

An example of improvement maintenance is an often breaking ball bearing. After the issue has been identified, maintenance engineer could try to come up with an improvement. This improvement could be a sturdier bearing, different type of bearing or possibly decreased lubrication interval. Or, if improvements to the bearing itself aren't possible, the component could be made more accessible, which decreases repair time. (Mobley, 2004, p. 8)



### 4.3 Corrective maintenance

Standard SFS-EN 13306 defines corrective maintenance as “maintenance carried out after fault recognition and intended to put an item into a state in which it can perform a required function” (Finnish Standards Association, 2010). Corrective maintenance is the most basic and simplest approach to maintenance, it is also known as Run-to-Failure maintenance. The logic of corrective maintenance is very simple, if it breaks down, it is to be fixed. Otherwise, it is not to be touched. When a fault occurs, the aim of corrective maintenance is to bring the machine back to its intended operational condition with minimum effects on machine utilization rate. According to Järviö & Lehtiö (2012, p.51) main steps of corrective maintenance are:

1. Trouble shooting
2. Fault recognition
3. Fault localization
4. Repair
5. Restoration of operating condition

If the capacity utilization rates are to be maximized, corrective maintenance is a poor approach due to its reactive nature. Corrective maintenance allows failures to occur, and therefore disturbances to capacity utilization rate can't be completely avoided. Due to its reactive nature, and because no effort is made to anticipate the maintenance requirements, maintenance department is forced to retain extensive spare part inventories to ensure sufficient reaction time. Corrective maintenance method also produces a low reliability environment, which leads to high overtime labor costs, high machine downtimes and low production availability. A repair executed in the corrective mode averages about three times the expenses than the same repair executed in the preventive mode. Ergo almost no maintenance organization employs corrective maintenance as a sole method of operation. (Mobley, 2002, pp. 2 - 3)

However, despite its vast defects, sometimes corrective maintenance is the only reasonable procedure to employ. All of the faults can't be foreseen, which leaves corrective maintenance the only available option. Secondly, at times, replacing a worn part before a fault occurs is not necessarily the most economical option. This is the case when a fault will only cause a minor disturbance to the capacity utilization rate or machine is of low value to the company.

#### 4.4 Preventive maintenance

Preventive maintenance is defined as “maintenance carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning of an item” (Finnish Standards Association, 2010). Preventive maintenance is a proactive process, aimed at reducing the probability of failure and maintaining the operational condition of a machine. Preventive maintenance is always either time or condition-driven. (Mobley, 2002, p. 3)

The process consists of four main elements: maintaining operational conditions, inspections, planned repairs and modernization. These elements comprise of regular procedures such as tracking and inspection of fault producing causes, lubrication servicing, structural maintenance, uphold of clean operating conditions and pre-planned repairing of machine. Usually these procedures are carried out in pre-determined time intervals or are triggered by certain condition. (Järviö & Lehtiö, 2012) (Dhillon, 2002)

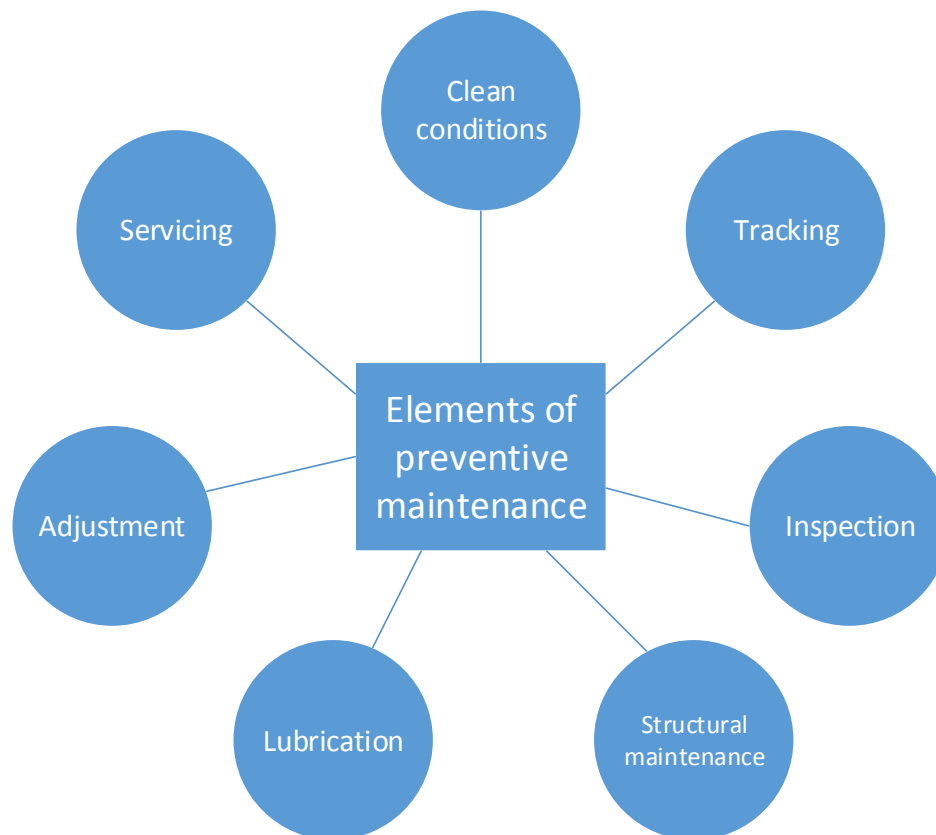


Figure 6 Elements of preventive maintenance (Dhillon, 2002)

Preventive maintenance applications vary greatly in practical implementation. Practical implementation depends on the type and importance of the machine. Generally it's economically sensible to schedule more thorough maintenances to machines that are vital to the production process. (Mobley, 2002, p. 3)

Preventive maintenance becomes a feasible option when the expenses of preventive maintenance are lower than the costs of faults and defects that preventive maintenance would have prevented. What percentage of total maintenance work should be preventive maintenance is, however, debatable. Different authors possess different views on the topic, but the view that preventive maintenance should form a major part of all maintenance work seems to be the general consensus. Figure 7 depicts the relationship between the ratio of maintenance types and costs. (Järviö & Lehtiö, 2012)

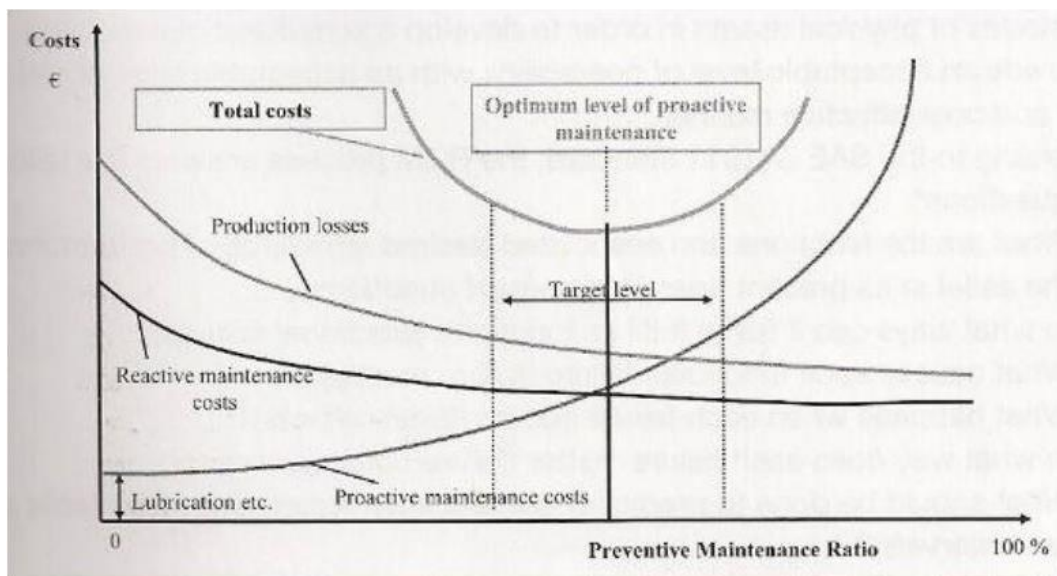


Figure 7 Preventive maintenance ratio related to cost (Leiviskä, 2009)

#### 4.4.1 Time-driven preventive maintenance

Time-driven preventive maintenance comprises all the preventive maintenance tasks that are triggered by time. Usually this is either absolute time or realized operating hours. MTBF is a common time-driven preventive maintenance scheduling tool. MTBF is measured by observing machine's fault history, namely the time between faults (figure 8). This way maintenance engineer can calculate the average time for a component or a machine to fail. This information is then taken advantage of by scheduling maintenances so that the maintenance interval is shorter than the MTBF interval.

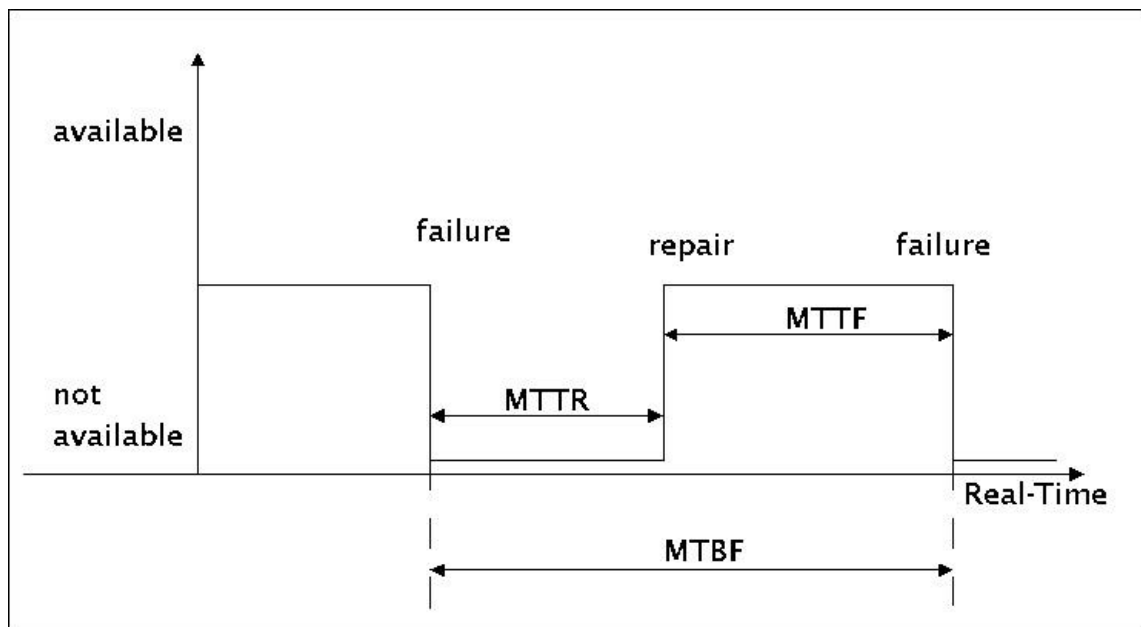


Figure 8 MTBF (Döben-Henisch)

According to the traditional model machines encounter the most failures when they are new and when they are close to the end of their lifecycle (figure 9). This can be taken advantage of by scheduling more maintenance works for these two timeframes. However, it should be taken into account that bathtub curve is just one failure model, and although quite common, doesn't necessarily always reflect reality. In those cases, other failure models must be adopted. (Järviö & Lehtiö, 2012, p. 76)

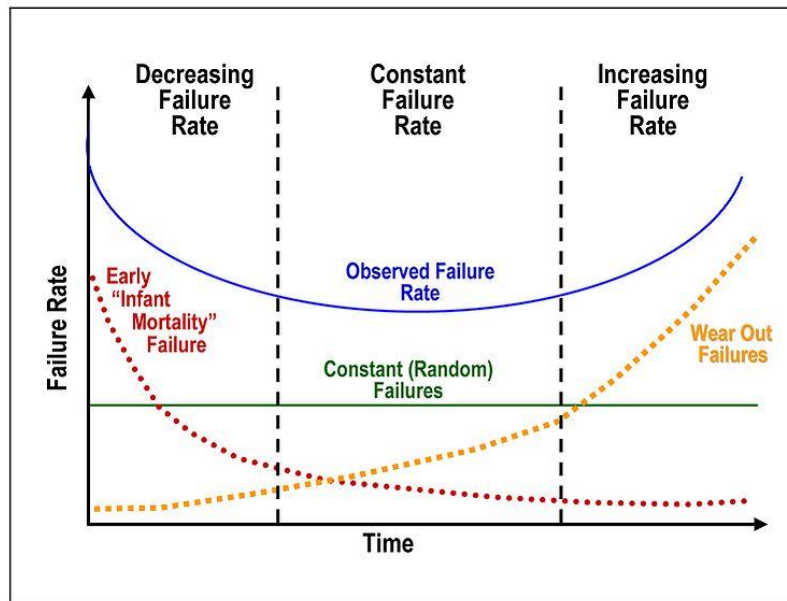


Figure 9 Bathtub curve (Wyatts, 2005)

Machine classification plays an important role in denominating the preventive maintenance procedures. Different types of machinery have different lifecycles and different maintenance needs, and this is taken into account in preventive maintenance. If machine's average expected lifecycle is 25 months, then correctly carried out preventive maintenance will remove and rebuild the machine after 24 months of operation. Obviously there lies a pitfall in this type of statistical forecasting of machine failure. This pitfall is the probability distribution. For example the machine in question could have functioned for more than 25 months, making preventive rebuild of machine a waste of resources. On the other hand, the machine could have broken before the scheduled rebuilding, creating a situation where corrective maintenance must be employed, production capacity is endangered, and maintenance costs increase. (Mobley, 2002, p. 4)

#### 4.4.2 Condition-driven preventive maintenance

In order to avoid this pitfall of strictly time-driven maintenance scheduling, preventive maintenance employs inspection of machine condition. These procedures can, while still being part of preventive maintenance, be called predictive maintenance. The idea is to track, measure, and analyze the mechanical condition, operating efficiency, and other indicators to deduce future maintenance requirements of the machine. The simplest form of predictive maintenance is visual inspection, but more complicated measures involve things like vibration measurements, infrared imaging and other non-invasive techniques. (Mobley, 2002, p. 5)

Predictive maintenance aims to avoid the two pitfalls of time-driven maintenance, which are unnecessary repairs and unscheduled outages. Predictive maintenance can be seen as a philosophy that uses the actual operating condition to optimize the preventive maintenance operations. Unlike pure time-driven preventive maintenance procedures, predictive maintenance is purely condition-driven. Traditionally condition-driven preventive maintenance is used as a maintenance management tool to prevent unscheduled downtime and failures, but predictive maintenance can also be used as an effective maintenance optimization tool. The aims of maintenance optimization via predictive maintenance should be to eliminate unnecessary maintenance tasks, to extend the lifecycle of systems, and to reduce the total lifecycle cost. (Mobley, 2002, p. 61)

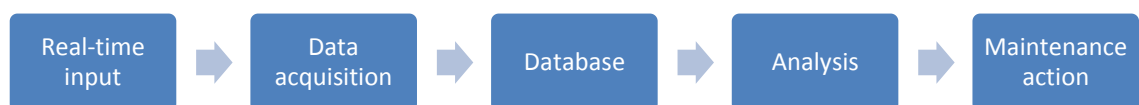


Figure 10 Predictive maintenance steps

#### 4.4.3 Involving operators to preventive maintenance

Involving operators to the maintenance process is one of the most essential elements of TPM. In TPM it is often referred as ODR. Even though TPM as a maintenance strategy is not addressed in this thesis, ODR offers some value as a standalone method. ODR aims to lower the boundary between maintenance and operators, thus enforcing joint liability of the condition of machines. ODR means that the operators perform simple maintenance tasks to their machines, and take charge of the condition of their machines. There tasks include simple inspections and cleaning. Usually machine operators are the ones who have the most information about the condition of their machines, after all they use them daily, so having them perform some simple daily and weekly visual inspections and cleanings only makes sense. And in the long run machine operators will gain more understanding of the machines they operate, thus improving their workmanship.

The aim of including operators is to save maintenance resources by moving the mundane and menial tasks to the operators. Usually ODR results in better availability of the machines, as operators become more skilled at spotting starting failures.

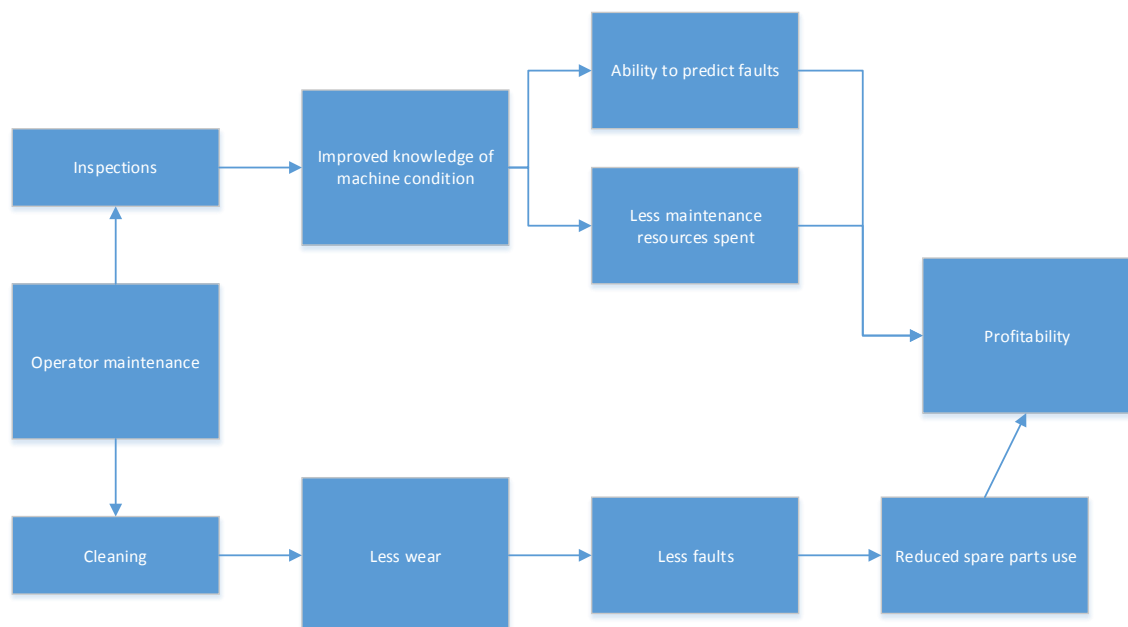


Figure 11 Effect of ODR on profit

#### **4.4.4 Requirements of preventive maintenance**

The number one factor for carrying out any successful maintenance management plan is the possession of factual data to quantify the actual need for repair and maintenance for plant machinery (Mobley, 2002, p. 1). Effective maintenance planning requires both component specific and system-wide scrutiny. It is important to measure and analyze performance of both individual component and the system to truly understand the cause of a fault. However, the system is what generates capacity and revenue, so the system should always be the priority.

The two main requisites for an effective preventing maintenance system are method and discipline. Firstly, method means that correct tasks are carried out at a best interval. Secondly, discipline means that all the tasks are planned and scheduled, and the whole team sticks to the plan. Effective maintenance is dependent on doing basic tasks that produce a reliable production environment. (Mobley, 2004, p. 12)

Inspections are a cornerstone for any preventive maintenance program. Inspections are often thought to require expensive, exotic equipment to be effective, but nothing could be farther from the truth. Simple, visual inspections are often the most efficient tool. They can often be even carried out when the machine is operating, which saves both the time of the technician and production time. Not to mention the exposure of equipment to damage it averts. (Mobley, 2004, p. 12)



Human senses are a tool often far undervalued and underemployed in detecting abnormalities in equipment action. Experience is generally the best teacher, and experienced technicians are able to spot abnormalities because they know what to expect. In order to efficiently utilize human senses training should be provided so employees know what to look for. In addition to training, standards provide a useful tool for comparisons. Pictures and worn-out parts can be displayed so the technicians receive a proper baseline for observations. (Mobley, 2004, p. 12)

Unfortunately humans are not continuously alert, and are not able to detect small differences, or get into small spaces. Therefore utilization of sensors is necessary in order to receive information of small changes when the machine is running. Progresses in sensor technology have made them an affordable option for maintenance applications. (Mobley, 2004, p. 12)

Thresholds are a necessity to determine when, and under what measurements, machine still operates safely and as it's designed to operate. In order to set the threshold, data must be collected to define what parameters can exist under normal operation, and what parameters lead to a failure. When the breaking point is known, a margin of safety is added to ensure adequate time to respond, this is called the threshold set point. Once the set point is established it must be monitored to detect when it is overridden. (Mobley, 2004, p. 14)

#### **4.4.5 Advantages of preventive maintenance**

Preventive maintenance is credited with multiple advantages over corrective maintenance. The main advantage is increased control over maintenance procedures because of proactive nature of preventive maintenance. The maintenance tasks can be planned to be performed at the most convenient times. This allows for improved use of maintenance resources while ensuring that production capacity is hindered as little as possible. Surprise breakdowns are reduced by employing preventive maintenance. This leads to reduced or eliminated overtime costs. However, in order to fully realize this benefit, preventive maintenance tasks must be appropriately scheduled. Because preventive maintenance permits planning of repairs, spare parts and material requirements can be anticipated so that the required parts and materials are available when they are needed. Thus smaller inventories are required which decreases inventory carrying costs. These advantages amount to serious savings in maintenance expenses. (Järviö & Lehtiö, 2012, p. 103)

It has also been observed that planning and scheduling maintenance tasks increases the productivity of maintenance personnel (Järviö & Lehtiö, 2012, p. 104). Preventive maintenance provides constant information about the condition of machines. Therefore it's easier to forecast reductions in machine availability and to act before downtime is required. This perk allows for reduced redundancy, meaning that less reserve capacity is required in order to secure the reliability of delivery. Safety of machines is also enhanced, as safety issues can be recognized in scheduled inspections of machines. And machines won't be allowed to deteriorate to a point where they might form a safety risk to the operators.

Constant inspection and information flow also enables maintenance to maintain machines in high quality producing condition. Tolerances are maintained through constant servicing and adjustments, and therefore less quality defects occur. Machine condition can be monitored through several predictive measures which allow the maintenance department to intervene before the quality of products is jeopardized. The power of predictive procedures has been noticed in the industry. In 2000 survey almost 77% of respondents cited improved product quality as a reason why a condition-based preventive maintenance program was implemented. (Mobley, 2002, p. 61)

Most importantly, preventive maintenance allows for a superior cost-benefit relationship (Mobley, 2002, p. 49). As stated previously, corrective maintenance is on average three times more costly than preventive maintenance. On the other hand, corrective maintenance method is the most economical in some cases. Preventive maintenance planning element allows the best of both worlds to be employed, creating a three-way balance between corrective maintenance, preventive maintenance, and production revenues (Mobley, 2002, p. 49).

Employing predictive technologies in preventive maintenance provides further improvements in maintenance. According to Mobley (2002, p. 70) “A survey of 500 plants that have implemented predictive maintenance methods indicates substantial improvements in reliability, availability, and operating costs”. In addition, the survey concluded that actual maintenance costs were reduced by 50% and unexpected machine failures by 55% on average. Also, companies were able to reduce spare part inventories by over 30% due to improved ability to predict equipment failures. Furthermore, regular monitoring and analysis of machine condition enabled a decrease of 60% in the time required to repair equipment. Moreover, condition-based preventive maintenance averts occurrence of serious damage through early detection. This early detection increased the useful lifecycle of equipment by 30%. All of these perks amount to a total increase in availability, which was observed to be a 30% increase. (Mobley, 2002, p. 72)

#### **4.4.6 Disadvantages of preventive maintenance**

Preventive maintenance, like any other thing, is not without its disadvantages. Several issues must be recognized and minimized to ensure optimal performance. Most important of these disadvantages is what Mobley (2002, p. 49) calls “potential damage”, meaning that every time maintenance tasks are carried out damage can occur through neglect, insufficient training, abuse, or faulty procedures. Maintenance is the cause of 17% of production downtime and 30% of failures are due to operational and maintenance errors: so potential damage is an issue to be taken seriously. (Dhillon, 2002, p. 117)

Scheduling preventive maintenance to preplanned maintenance intervals increases part use. Replacing parts during preplanned maintenance obviously cuts their lifecycle short compared to waiting until a part failure occurs. This is an obvious disadvantage, but often when a trade-off between parts, labor and downtime is in question, the cost of downtime and labor outweighs the cost of increased parts use. (Mobley, 2002, p. 50)

When equipment utilization rates are high access to equipment might turn out to be challenging. In preventive maintenance access to equipment is required more often than in corrective maintenance. A good preventive maintenance program requires the support and willingness of production to coordinate the availability and to create time for equipment inspections. (Mobley, 2002, p. 50)

## 5 THEORY OF DESIGNING A MAINTENANCE PROGRAM

Despite the importance of maintenance, there is no universally best method for designing a maintenance program, because maintenance structure depends largely on company's industry and objectives (Ben-Daya et. al, 2009, p. 4). Maintenance strategy should stem from the identification of operating aspects and business objectives (Kelly, Maintenance Organization and Systems, 2003). Thus maintenance strategy decisions should be composed with manufacturing and business strategies in mind, and instead of being its own entity, should aim to support these and be consistent with the overall business strategy.

Companies often try to optimize maintenance by using a ratio of preventive and corrective maintenance as an indicator. This approach creates an obvious issue: preventive maintenance is often increased erratically instead of using a well-constructed plan in order to ensure maximum effectiveness. Furthermore, often maintenance strategy only focuses on few aspects of maintenance leading to dumbing down of maintenance to just preventive or corrective. It is extremely important to understand maintenance function as a holistic approach to avoid these pitfalls. (Pintelon;Pinjala;& Vereecke, 2006) (Salonen & Deleryd, 2011) Figure 12 showcases the pitfalls associated with maintenance program design as a cost matrix. In this matrix, non-conformance costs are to be avoided by employing correct maintenance program design.

	Corrective maintenance	Preventive maintenance
Cost of Conformance	<b>Indispensable corrective maintenance:</b>  Corrective Maintenance due to: <ul style="list-style-type: none"> <li>- Failures with random distribution and no measurable deterioration</li> <li>- Failures which are not financially justified to prevent</li> </ul>	<b>Valid preventive maintenance:</b>  Preventive Maintenance, necessary to uphold necessary dependability Improvements intended to increase the reliability of equipment
Cost of Non-conformance	<b>Non-accepted corrective maintenance:</b>  Corrective Maintenance due to: <ul style="list-style-type: none"> <li>- Lack of preventive maintenance</li> <li>- Poorly performed preventive maintenance</li> <li>- Poor equipment reliability</li> </ul>	<b>Poor preventive maintenance:</b>  Unnecessary Preventive Maintenance Poorly performed Preventive Maintenance

Figure 12 Cost of non-conformance (Salonen & Deleryd, 2011)

Maintenance decision is always a trade-off between resources, output and risk. A framework proposed by Tam and Price (2008) displays this in figure 13. According to Tam and Price, there are three critical dimensions in maintenance decision-making. These dimensions are output, risk and resources, and these dimensions denominate the maintenance strategy and procedures.

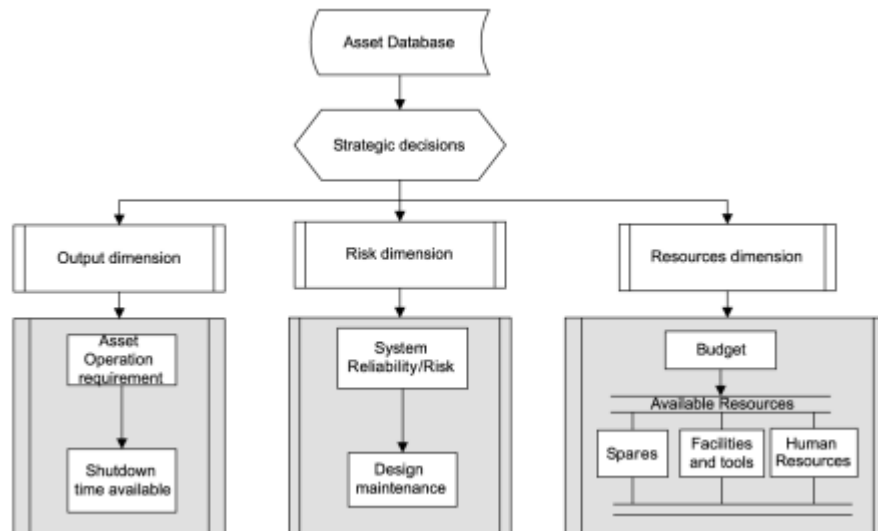


Figure 13 Maintenance decision (Tam & Price, 2008)

As seen from figure 13, the question for designing an effective maintenance program is not necessarily: what is the best maintenance procedure to perform. But rather, what is the maintenance procedure that will provide the best return on investment given the time and resource restrictions.

## **6 THEORY OF DESIGNING A PREVENTIVE MAINTENANCE PROGRAM**

Designing of preventive maintenance is traditionally one of the hardest areas of maintenance management. It is extremely hard to define practices that would produce the best return on investment. As a result, preventive maintenance programs are often plagued with over assignment of tasks or contain ineffective procedures. It is estimated that up to 33% of maintenance resources are wasted performing ineffective tasks. (Järviö & Lehtiö, 2012, p. 100) (Mobley, 2002, p. 1)

Pivotal features of a preventive maintenance system are planning, scheduling and discipline (Mobley, 2002, p. 1). When tasks are efficiently planned for, production delays are minimized. Scheduling makes sure that delays between maintenance works are minimized, and hence usable maintenance resources are maximized (Järviö & Lehtiö, 2012, p. 100). Discipline means that organization must have the required discipline to stick to the planned maintenances and enforce the quality of maintenance work. Valid failure data provides the basis for an effective preventive maintenance system. Hence, in order to succeed in implementing preventive maintenance, it is of utmost importance to have enough failure data to evaluate.

Usually the tasks are designed based on information about earlier fault occurrences, machine type and its function, and the machine manufacturer's recommendations. When designing an effective preventive maintenance system, one must include both time-driven and condition-driven tasks. Machine type and machine importance determine the employed maintenance tasks. Usually it's a mix of time-driven and condition-driven tasks that ensure the best possible maintenance outcome. (Mobley, 2002, p. 50) (Järviö & Lehtiö, 2012, p. 100)

For optimum preventive maintenance program it's vital not to over assign tasks, but on the other hand one can't under assign tasks either. In an event of over or under assigning the system is no longer efficient. Over assigning leads to wasted resources, while providing only little return on your investment. Under assigning, on the other hand, leads to lowered production capacity due to too often occurring faults. This then drifts the maintenance towards reactive procedures, which are three times as costly as preventive ones, leading to rising maintenance expenses and a drop in overall productivity of the plant.

When determining targets and intervals for preventive maintenance, following factors must be taken into consideration:

- Machine lifecycle
- Criticality of machine
- Technical level of machine
- Value of machine and cost of parts
- Working conditions

Criticality analysis can be executed to determine what machines benefit the most from preventive maintenance. In this way maintenance resources can be allocated in the most beneficial way. Unfortunately, criticality analysis doesn't answer to the question "how often". This is often best determined by observing MTBF figures and manufacturer's recommendations.

There are six steps to developing an effective preventive maintenance program (Dhillon, 2002):

1. Identify and choose the machines, components or areas
2. Identify the PM needs
3. Establish assignment frequency
4. Prepare the PM assignments
5. Schedule the PM assignments
6. Expand the PM program to other areas



## 7 CREATION OF THE PREVENTIVE MAINTENANCE PLAN

### 7.1 Mission statement

This work stemmed from the need of Purso Oy to update their preventive maintenance plans for their light metal workshop department. The goal of this thesis work was to overhaul existing maintenance plans, and to create new maintenance plans for machines lacking a preventive maintenance plan.

In order to guarantee comprehensive service, Purso Oy offers light metal refining services to its customers. “The light metal workshop is one link in the manufacturing chain spanning from the extrusion billet to the component ordered by the customer.” (Purso Oy, 2013). The light metal workshop offers different refining services such as bending, machining, welding, cutting, punching, finishing, assembly and packing. These procedures ensure comprehensive and flexible service to the customer. The workshop operates in three shifts during the weekdays and is shut down during the weekends. This amounts to 15 shifts a week and theoretical operating time of 120 hours.

Workshop’s maintenance strategy had previously been mainly that of corrective maintenance with a few scheduled lubrications and inspections. This has been an apt method given the small importance of the workshop to company’s revenue, type of machines and higher priority of other production departments. However, over the years demand for workshop products has increased up to the point that production capacity increase became timely. Problems with production capacity were solved by investing in new, more effective machines. This generated the need to design a preventive maintenance program for these new machines.

In order to treasure business secrets of Purso Oy, none of the machines of the light metal workshop will be referred by name in this thesis.

## 7.2 Planning and objectives

In a meeting with the service manager the scope of the thesis was limited to include preventive maintenances performed either daily, weekly, or monthly. It was concluded that the aim of the maintenance plan would be to prolong the lifecycle of new machines and to enable high effective utilization rates of machines while using as little maintenance resources as possible.

It was clear that in order to enable high capacity utilization rates two conditions must be met. Firstly, maintenances must cover all the most critical areas of a machine. This means that high risk parts and recurrent faults must be identified and maintenance resources must be directed at them. Secondly, maintenance must not cause unnecessary downtime. So maintenance must either be short in duration or carried out when a machine is offline anyways.

It was conceived that the best approach to this task would be to familiarize the machines first. Then the information in the CMMS is to be updated, if it's outdated. Third step would be to overhaul existing maintenance plans, and lastly the creation of new maintenance plans for the machines requiring them.

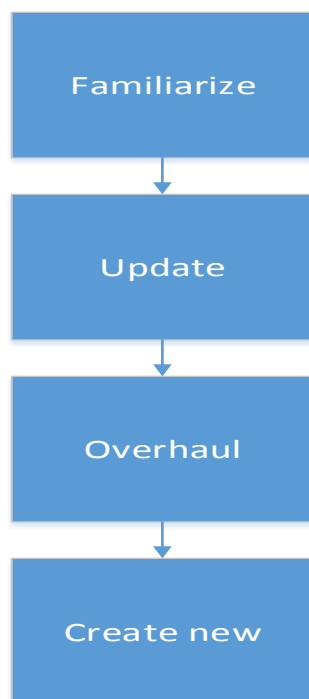


Figure 14 Progress of the thesis work

### 7.3 Starting phase

As planned, the work began by further inspecting the equipment base of the workshop. All of the machines were inspected, taking advantage of a floor plan of the workshop. During the inspection, the importance and function of different machines was also taken note of. Also it was made sure all the information in the computerized maintenance management system was correct and up to date. Basically the floor plan was used to go through the workshop, marking off the machines, checking relevant information like type number and model and also observing the use of the machine. Some of the information in the CMMS was out of date, so the required information was updated. Also machines that had already been removed from operation, but were still in the system, were removed from the CMMS. Also the equipment that was operational, but had not yet been added to the program, was added to fully bring the CMMS up to date.

Then existing maintenance plans were perused. Existing maintenance plans were available in the CMMS, where they could be read and modified. In most of the cases the maintenance plans were up to date and didn't require any further actions to be taken. In some of the cases further inspections and lubrications were added to some of the machines that would benefit from these tasks. By and large the existing maintenance plans were left as they were. Existing maintenance plans also served as a good base, on which new maintenance plans could be sketched. Using existing maintenance plans as a base ensured continuity in terms of style, layout, timing interval and task phrasing.

#### 7.4 Planning the preventive maintenance program

Then the work on creating new maintenance plans to the machines that didn't have any yet was embarked on. Dhillon's (2002, p. 49) six steps of preventive maintenance design framework was employed as a base for the design of maintenance plans. This outline divided designing of preventive maintenance program to clear and sensible steps. At this point, the areas were already identified and chosen in the initial meeting with the service manager. And since the machine lists and existing maintenance works were already examined, the machines that required preventive maintenance plans were solved. This allowed moving directly to the "identify PM needs" step.

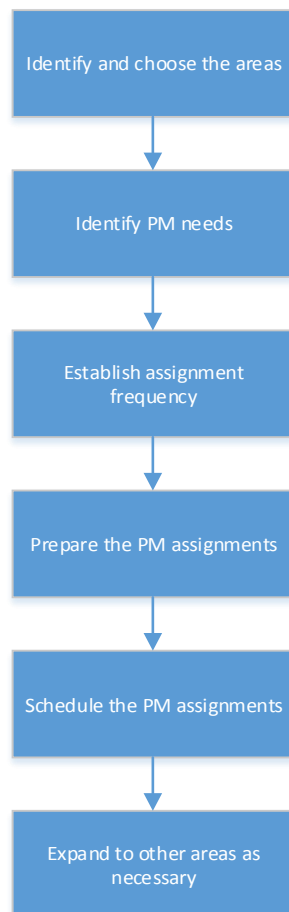


Figure 15 Six steps of preventive maintenance design (Dhillon, 2002, p. 49)

## **7.5 Identifying PM needs**

In this phase of the design process the PM needs of the machines were identified. In order to choose the right quantity of PM tasks, the relative importance of machines in the light metal workshop should be known. Therefore criticality analysis was employed to determine the most critical machines. This allowed correct allocation of resources to maintaining the right machines. Secondly, in order to make erudite decisions about the PM needs data of the machines is required. Collecting data allows determining which components of the machines need inspections, lubrications and such.

### **7.5.1 Criticality analysis**

The criticality of different machines was largely evaluated based on their run time. Most of the workshop machines run in one shift, and therefore these machines aren't as critical to production capacity as machines running in three shifts. Should a breakdown occur, those can most likely be fixed during the remaining two shifts since maintenance operates in three shifts anyways. Also, information about the importance of different machines was received from the workers of maintenance department.

A criticality analysis list was then composed based on the collected information (attachment 1). The newest machines had the most run time and their designed capacity utilization rate was high. Also these machines were the most complex in the workshop. Therefore it was concluded that preventive maintenance would be most cost efficient to these machines. This inspection left two machines that would receive most of the maintenance. These were in the most critical class, and also didn't have existing maintenance programs. These machines can't be named in this thesis due to business secret reasons, so from now on the machines in question are going to be referred as Machine 1 and Machine 2.

### 7.5.2 Data collection

Once the existing machines were inspected, and the information brought up to date, began the data collection phase of my work. The aim in this phase was to collect as much relevant data as possible. As explained in the “requirements of preventive maintenance” section, sufficient data is one of the cornerstones of an effective preventive maintenance program.

Firstly, this phase was embarked on by going through all the manuals provided by machine manufacturers. Luckily these manuals were in store, and easily accessible for all the critical machines. Based on these manuals a decent list of lubrications and other maintenance procedures, specified by the manufacturers, was collected.

Secondly, after tapping the manuals dry, the direction of data collection efforts was moved to CMMS program. The program contained extensive fault history for most machines, spanning through the whole realized lifecycle of the machines. Fault history contained the dates of fault occurrence, fault description, and repair procedure performed. Based on this fault history a list of often-occurring faults and faults that would have been easy to prevent by employing inspection measures was composed.

Thirdly, expert opinion to define possible points of intervention was taken advantage of. In this case expert opinion was the opinion of seasoned maintenance technicians who were interviewed about the defects of the machines.

Forthly, the machines were observed in function and also all the structures were inspected. The above steps of data collection gave a baseline of information to which to compare my observations. Attention was paid to things like revolving speed and load bearing of different laurels, rate of use of different linear guides, and cleanliness of machine and its immediate environment.

Lastly, related literature was referenced to ascertain of best practices for maintenance, inspections, lubrication and oil change intervals.

## **7.6 Resolving the maintenance intervals**

The maintenance intervals were mainly influenced by three factors: manufacturer's instructions, earlier practices regarding similar components and common sense. It was concluded that calculating the theoretical re-lubrication interval of bearings and linear guides was too big of a task to undertake, because a single machine could have over 100 different bearings under different rpms and loads. So a method of estimation and comparing to existing lubrication intervals for similar components was used. Mostly the lubrication intervals were kept where the manufacturer had set them, because of scheduling issues. The monthly maintenances were going to be carried out on specific days of the month, so therefore the options were either to keep the lubrication interval monthly, double the lubrication interval or remove the lubrication from monthly maintenances all together. And, anyhow, it is not feasible to schedule lubrications to multiple different timeframes. This would just waste maintenance resources without providing any real benefit.

## **7.7 Resolving the preventive maintenance tasks**

This task was begun by taking a look at the data collected. Firstly, the list of maintenance tasks recommended by machine manufacturers was examined. Mainly these consisted of lubrications and different inspections. Often manufacturers have a good incentive to overdesign maintenances, and this was taken into account. After all it's not the manufacturer's loss when machines are at standstill, but it is the manufacturer's loss when machines break. So there is a clear incentive to overdesign on part of the manufacturer.

So after getting a list of maintenance tasks from machine manufacturer recommendations, an inspection was conducted. It was made sure that all the lubrication points were factually there and that all of the manufacturer's information was correct. Here the list of fault history I had composed earlier while collecting information about the machines was also taken into account. Cleanliness, or rather lack of, was another thing taken note of. Colleagues also expressed wishes that regular cleaning would be necessary. Especially the saws of the workshop tend to collect aluminium dust and chips. The dust and

chips can affect the function of different sensors and cause wear to joints, bearings and linear guides. Dirtiness of machines also retards repair and maintenance efforts, because then the technicians have to clean the machine before they can determine the fault or carry out repairs. This in turn increases the time required to perform repairs. Therefore it was concluded that weekly and daily cleaning tasks were effective use of time.

Safety measures were also taken into account when devising the preventive maintenance tasks. To improve worker safety emergency stop and optical safety sensor function was scheduled to be checked once a month.

Then examination of the gathered maintenance tasks was started. The question, whether a task was something that was going to add any extra value, was posed to determine the relative importance of the task. The wear that the components are under and the conditions the machines are under were taken into account, for example the rpm and the loads a single bearing is subjected to. This inspection led me to drop some of the low reward – high workload maintenance tasks, because the objective was to produce an effective and efficient preventive maintenance program.

In the following two chapters examples of resolving maintenance tasks for two different machines are examined. This way the reader can get a grasp of the kind of decisions taken while resolving the maintenance tasks. The examination of resolving maintenance tasks is limited to only two machines, even though maintenance tasks were assigned to multiple machines, because of space constraints.



### 7.7.1 Machine 1

For machine 1 most of the maintenance works were based on existing lubrication charts. However, a lot of bearing lubrications were discarded. For example, lubrication of 75 bearings was discarded. Originally the manufacturer recommended a monthly lubrication. But after referencing the literature (Bartels et. al, 2007, p. 680) (Anttila et. al, 2004, pp. 205-206), and especially the re-lubrication chart, it was concluded that the revolving speeds were too slow to warrant regular lubrication. Therefore moving the lubrication of these bearings to yearly maintenance would be the most cost-efficient choice. This decision alone allowed reducing the required maintenance time significantly.

The lubrication of vertical racks that had automatic lubrication unit was also prolonged. Similar racks are used in multiple machines of the factory, and cleaning and re-greasing interval for these racks is one year. This is an interval that has been proven to be adequate in practice, so I saw no reason to commit to more frequent re-greasing.

On the other hand, two new lubrication tasks that weren't determined in the lubrication charts were added. Most likely they weren't in the lubrication charts because the conveyor belt isn't considered to be part of the machine the manufacturer sells. In any case, it was concluded that the bearing of the conveyor belt would benefit from monthly lubrication. Other lubrication tasks added were chains of different electric motors. It was decided that it would be best to lubricate these chains in order to impede unnecessary wear.

Looking at the fault history data, it was taken note that a certain lift mechanism had had loose attachments. This was another easy visual inspection that was added, because the inspection was regarded to be low workload but high possible return. There were also some consumable items that were quite often replaced due to wear. Since visual inspection of these items was very straightforward, these items were added to the inspection list. This way the replacements of these parts could be planned in advance.

In order to maintain good level of cleanliness, some cleaning tasks were added. Firstly, cleaning of linear guides and their surroundings was added. These linear guides are often exposed to a lot of aluminium dust and chips, and therefore their surroundings should be kept clean. I also added vacuuming of the interior of Machine 1 to the list. This was based on the notion that similar types of machines have been in use earlier in the factory, and these machines encountered faults due to aluminium chips and dust in the interior.

### **7.7.2 Machine 2**

As in the case of Machine 1, also Machine 2's preventive maintenance tasks were largely based on manufacturer's recommendations. In this case, the manufacturer's maintenance recommendations were a bit too heavy. So the PM tasks process was started off by eliminating some of the recommended daily cleanings that weren't at all necessary. It was observed that some of the recommended spots didn't get dirty during normal operating of the machine, therefore cleaning them every day would be a waste of time. Other originally daily task that was prolonged was the cleaning or replacing of filter of an electric center. Earlier experience has shown that the filters don't get dirty nearly that fast, and monthly cleaning or replacing was a much better interval given the location and conditions. Eliminating some of the less important cleanings saves operator's time, which is otherwise directly away from production.

Inspection of micro switches was also disregarded. Typically these heavy duty switches have a very long lifetime, somewhere up to ten million cycles, so weekly or daily inspection of these micro switches was deemed to be not necessary.

Some impossible to perform tasks were also discarded, such as cleaning pollutants from the two oil tanks. There is no way for maintenance personnel to see into the tanks whether there are some impeding obstacles in the tanks, let alone removing them.

## 7.8 Creation of the preventive maintenance program

After the tasks and intervals were determined, composition of the actual program was started. Here there were a couple of main issues to resolve. The first issue was determining the optimum work allocation. Meaning that, the maintenance tasks had to be assigned so that the use of resources is optimized. Second issue was determining the medium of information distribution. Meaning that, a way in which maintenance tasks would be most efficiently distributed and understood was to be designed.

The first problem was tackled by considering assigning some of the maintenance tasks to machine operators. The idea was to assign simple, daily and weekly, inspections to machine operators. This idea abides to the TPM principles of involving production departments to the maintenance process. When the service manager was shown the proposed PM task list and intervals, he also suggested assigning some of the works to machine operators. This decision saves up valuable maintenance resources that could then be directed to more productive endeavours. On top of saving maintenance resources, it obliges machine operators to pay attention to the condition of machine they are operating. Some of the other benefits are listed in the theory section of this thesis. The more complicated maintenance tasks were assigned to the maintenance personnel. This ensures maximum quality of work and familiarizes maintenance personnel with the machines.

Second problem of information distribution was decided to be solved by creating graphical maintenance instructions for the most critical and complex machines. This is actually something that was discussed about doing with the service manager earlier. It was decided not to create maintenance instructions for the most basic tasks. It seemed that there wouldn't be any added value by having instructions for the tasks that everyone knows how to perform.

Extensive instructions achieve two important objectives. Firstly, clear instructions ensure that the maintenance task is properly understood and correctly performed. This reduces the possibility of human error and creates a standard to performing maintenance tasks (Dhillon, 2002, p. 122). If instructions are ambiguous different technicians may do the maintenances differently, or even worse, misunderstand some of the procedures, and

this is counterproductive or even hazardous. Secondly, maintenance instructions reduce the training required. Maintenances are not necessarily carried out by the same person due to vacations, sick leave or a myriad of other possible reasons. Instructions enable anyone to carry out the maintenances without requiring special training. This ensures that the maintenances are carried out even though the responsible person isn't available to perform them.

## **7.9 Creation of maintenance instructions**

Graphical maintenance instructions were created for the most critical machines of the workshop (attachment 2). In cases of some machines, the manufacturer had included graphical maintenance instructions. Advantage of the existing pictures and formats was taken as much as possible. In other cases, pictures were taken and demonstrative elements and numbers added to the pictures. The floor plan was also added to the instructions, because colleagues expressed, that sometimes finding the correct machines is difficult due to the sheer number of machines the workshop has. With a floor plan attached to the instructions, finding the correct machines will be much easier.

A checklist for operator-driven inspections was also created (attachment 3). Since machine operators don't have access to the computerized maintenance management system they can't sign the tasks there, therefore a checklist was required. Operators have to indicate that they have carried out the maintenance tasks by signing the form. This enforces execution of inspections by creating incentive to actually carry out the procedures.

## 7.10 Scheduling

There were two major restrictions in scheduling the preventive maintenance program. These were maintenance resources and production requirements. The workshop's management wanted the preventive maintenances to cause as little disturbance to production as possible. As stated above, the workshop worked three shifts during the weekdays and was down during the weekend, so in order to minimize disturbances to production the best time to perform maintenances would have been during the weekend. And in the perfect world that would have been what we would have done.

But maintenance resources were fully bound to the maintenances of the aluminium extrusion factory during weekends. Maintaining everything directly related to extrusion is the main priority of the maintenance department and workshops are a secondary priority. So obviously scheduling maintenances to the weekends wasn't an option. In a meeting with the workshop's management we concluded that the best option for both departments would be to schedule maintenance of the most critical machines on two different weekdays. On top of this it was concluded that the maintenances would be started while operators are having their lunch break. Since the less critical machines have the shortest run time, it was agreed that the less critical machines would be maintained during the night shifts. The main priority of the night shift is keeping the extrusion lines running. However, at times there are not a lot of faults to respond to, and the night shifts are underemployed. Therefore performing maintenance to the workshop is something night shift maintenance personnel can do if nothing more urgent turns up.

By dint of this solution the best compromise was achieved, given the restrictions. The maintenances can be carried out during the weekdays that generally have the least production, and maintenances are timed so that disturbance to the production can be minimized. This allows retaining of high capacity utilization rates while minimizing the maintenance workload during weekends.

## **7.11 Implementation**

As the first task it was made sure all of the machines had an identification number plate clearly visible on them. For the machines that didn't have, one was made. Identification number plates allow the technicians to easily distinguish the right machine to service. For example, there are multiple forklifts that are of the same type. Identification plates allow the technicians to know which forklift to service without having to look for a manufacturing number or other such information.

The maintenance department utilized a CMMS in scheduling maintenances and in keeping track of performed tasks and faults. In order for the workshop's preventive maintenances to take effect they had to be entered to the system as scheduled maintenance works. So therefore that was the second task of implementation that was undertaken. Inputting new maintenance works to the system was relatively easy. The program enabled setting fixed time interval tasks, which was utilized to make the tasks appear weekly and monthly.

## 8 CONCLUSION

The aim of this project was designing and creation of preventive maintenance program that included the machines of workshop and bending shop of Purso Oy. The objective of the preventive maintenance program was to respond to the maintenance challenges the growth of workshop production demand necessitated. Namely, the maintenance issues of new equipment.

The utilized method was a modification of Dhillon's (2002, p. 49) framework solution for preventive maintenance design. The work progressed by adapting the steps Dhillon proposed in his book. By and large, the method proved to be an effective tool in preventive maintenance planning. The steps progressed in sensible order leading to the completion of the preventive maintenance plan.

At the time of writing this the preventive maintenance plan has not taken effect yet. Therefore drawing any factual conclusions about the degree of success seems immature. However, that being said, I feel that the preventive maintenance program I devised met or surpassed most of my personal goals.

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